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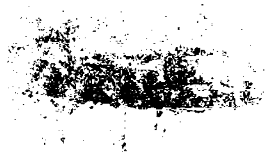
# EVALUATION OF QUARRYING AND ASPHALT CONSTRUCTION EQUIPMENT




by

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US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

September 1988

Final Report


DEPARTMENT OF THE ARMY
US Army Engineer School
Fort Belvoir, Virginia 22060-5281

Project Order No. DCD PO-01-86


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New equipment and construction techniques are being developed and incorporated by industry to quarry and produce aggregates and for the mixing and construction of asphalt concrete pavements. This report is a presentation of those developments and the pertinent pieces of equipment that could readily be incorporated into the Army's inventory. The incorporation of this equipment would enable units to significantly increase material production with compact, readily transportable machinery with negligible impact on Table of Organization and Equipment allotments.


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| Asphalt mixing equipment | Quarry material transportation |

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# PREFACE

This study was conducted by the Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, for the Directorate of Combat Developments (ATZA-CDC), US Army Engineer School, Fort Belvoir, Virginia. CPT Neil J. Clemence was the Project Officer. This report describes the results obtained from the project entitled "Quarry and Asphalt." The study was conducted from 25 September 1986 through 31 August 1987 under Project Order No. DCD PO-01-86.

The study was conducted under the general supervision of Dr. W. F. Marcuson III, Chief, GL; Messrs. H. H. Ulery, Jr., Chief, Pavements System Division (PSD), GL; J. W. Hall, Jr., Chief, Engineering Investigation, Testing, and Validation Group (EIT&V), PSD, GL; and L. N. Godwin, Chief, Material Research Center, EIT&V, PSD, GL. This report was prepared by Mr. R. R. Johnson, PSD. Mrs. J. H. Walker, Information Products Division, Information Technology Laboratory, edited the report.

COL Dwayne G. Lee, EN, is Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

CONTENTS

## CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

| Multiply | By | To Obtain |
|---|---|---|
| British thermal units | 1054.0 | joules |
| cubic feet | 0.02831685 | cubic metres |
| cubic yards | 0.7645549 | cubic metres |
| feet | 0.3048 | metres |
| gallons | 3.785412 | cubic decimetres |
| gallons per minute | 0.00006309 | metres per second |
| horsepower (550 foot pounds (force) per second) | 745.6999 | watts |
| inches | 2.54 | centimetres |
| tons (2,000 pounds, mass) | 907.1847 | kilograms |

# EVALUATION OF QUARRYING AND ASPHALT CONSTRUCTION EQUIPMENT

## PART I: INTRODUCTION

### Background

1. The United States Army Engineer School (ATZA), Fort Belvoir, Virginia, requested the assistance of the Waterways Experiment Station (WES) in identifying the Army's worldwide quarry and asphalt requirements. The initial study was to determine the manpower, equipment, and material requirements. By amended Project Order No. DCD PO-01-86, dated 25 September 1986, the study was redirected to focus on the Army's existing equipment's capabilities and the possibility of the requirement for an all new equipment specification to fulfill the engineer units quarrying and asphalt missions.

2. Utilizing preliminary information provided by ATZA, contacts were made with Deputy Chief of Staff for Logistics Office (DALO), Equipment Planning and Distribution Division, to obtain information concerning the capability, condition, and capacity of quarry and asphalt equipment now being used by the engineer units. Initial response to the request revealed that the quarrying equipment consisted of remnants of 145 crushers purchased through four contracts from 1962 through 1967. These crushers, which are a jaw-roll configuration, are rated as 75 tons/hr units. Due to their age and, in some instances, the difficulty obtaining spare parts, their production efficiency has been greatly reduced.

3. WES was notified by ATZA that the quarry asphalt study was high on the priority list, but it was below the budget cutoff line and would not receive additional funding as originally planned. Following notification by ATZA of their limited resources and the constraining of their resources for the quarry and asphalt study, WES proposed that an effort be made to salvage and utilize portions of the information that had been assimilated. ATZA concurred and amended the scope of the work by a project order dated 13 January 1987 to request that WES research the state of the art of techniques and equipment being developed by industry for quarrying and asphalt production. The study was to focus on equipment with future military application and its ability to be incorporated into the Army's inventory.

## Objective

4. The objective of this study was to evaluate present-day construction procedures and methods that are being used by industry for aggregate production and the mixing and placing of asphalt concrete. The evaluation was to concentrate on new equipment that has been developed and its potential for military application. Consideration was to be given to the new equipment's manpower requirements for operation and maintenance and to the necessity for specialized controls and environmental requirements, i.e. air-conditioning or dust-free atmosphere for sophisticated computer operation that would be required for the equipment's operation.

## Scope

5. The objective of this study was accomplished by reviewing equipment information and specifications that were provided by 56 aggregate processing equipment manufacturers and 30 asphalt equipment manufacturers. The manufacturers producing equipment with apparent military potential were contacted or visited to obtain in-depth information about selected individual pieces of equipment. Additional information was obtained from Tinsman 1982 and by reviewing sample Table of Organization and Equipment manuals. The National Stone Association and the National Asphalt Pavement Association were also contacted requesting information. Two heavy equipment demonstrations were attended to obtain further product and equipment information.

## PART II: QUARRY EQUIPMENT

6. Part II of this report focuses on the primary pieces of equipment that are used for quarry operations. Auxiliary components and support equipment such as conveyors, loaders, and generators are not discussed.

7. Pertinent equipment listed in a standard Table of Organization and Equipment is as follows:

   a. Line item No. S03225 ROCK DRILLING EQUIPMENT.

   b. Line item No. X44393 TRUCK DUMP: 15 ton Diesel Driven.

   c. Line item No. F49399 CRUSH SCREEN PLANT: Diesel/Electrical Drvn 75 tons/hr.

8. Rock drilling equipment

   a. State of the art: Air-powered crawler drilling equipment continues to be the primary method of blast hole preparation in the United States quarrying industry. There have been several improvements and modifications made to the basic crawler air-track drill in the past 10 yr.

   b. New equipment and developments:

      (1) New cycle and piston designs of the drifters, or drilling heads, have reduced the quantities of air required to operate the drills. This improved drifter design allows for a reduction in the size of compressor required to operate the equipment and, depending on the size of the compressor, can reduce fuel consumption 2 to 4 gal/hr.

      (2) The introduction of the extendable boom on some models of crawler drills enables the equipment to drill numerous holes before the chassis has to be relocated. The extendable boom not only eliminates the need to relocate or reposition the drill for each individual hole, thereby reducing the time for setup, but also enables the equipment to drill on steep slopes and reach out over banks and ledges, both of which are very desirable for quarry development or exploration in rough terrain construction.

      (3) These two new developments are not addressed by Military Specification MIL-D-21201F Track Drills. To take advantage of these equipment improvements will require the Army's updating or modifying the specification.

      (4) The introduction of hydraulically powered drilling equipment into the US rock drilling industry is the biggest new development or radical change to the state of the art of blast hole preparation procedures. Hydraulic drills are favored by the European drillers but have just recently begun to be accepted by the US rock drilling industry. The hydraulically operated drills are gaining acceptance because they are produced as single self-supporting units

and do not have to tow and drag air hoses and an air compressor. These units are being manufactured with options or accessories such as air-conditioned cabs, automatic rod changers, dust collection systems, and dual controls. One set of controls is located in the cab, or operation platform, and the second set is located on the drill rod boom. These single self-contained units, equipped with automatic accessories, permit a single operator to perform more work in a shorter period of time, essentially increasing production with lower equipment and labor costs. The hydraulic operated drifters or drilling motors operate by delivering numerous high-frequency (2,600 blows/min (BPM)) of low intensity impacts to the drill rods; whereas, with air-operated drifters 1,200 to 1,500 BPM of high intensity impact are delivered to the drill rods. The hydraulic approach or procedure results in higher production rates using less horsepower, and they use approximately one-half the fuel of the equipment in the Army's inventory that were manufactured to meet the requirements of Military Specification MIL-D-21201F (Track Drills). The hydraulic drills are not only proving to be efficient and economical to operate but are also producing less noise pollutant; when they are equipped with a dust collector, they are producing much less air pollutant to the surrounding environment than are the air drills now being used by engineering units which are being operated without pollutant control equipment.

(5) A possible disadvantage of the hydraulic drill is that it does not have as much reverse lift or pulling power as does the air drill. This capability is desirable when it becomes necessary to dislodge drilling rods from the drill hole during drilling operations. In addition, a change to the hydraulic operated drilling equipment would require a large inventory of spare parts, i.e., pumps, hoses, service valves, o-rings, and filters to maintain the equipment. Strict maintenance procedures would also be required to keep the equipment operational in a remote harsh environment.*

(6) An additional new modification to rock drilling equipment being developed is a crawler drill that receives its maneuverability power from a hydraulic source. The drifter or drill continues to receive its power from a compressor mounted on the crawler chassis, but the operation of the propelling force by hydraulic drive instead of by air drive reduces the unit's air requirements by about 60 cu ft/min. The reduction of air requirements allows for a smaller, more compact air compressor to be mounted on the drill frame chassis. The one-piece, self-contained unit allows

* The US Navy is currently taking delivery of seven hydraulic drills for their construction battalions.

for better mobility and transportability of drilling equipment.

(7) The quarrying industry is operating on the principle that the fastest and most economical procedure to fracture rock for construction purposes is to presize the rock during blasting operations. The science of drill hole size and spacing in various types of materials and the sequencing and timing of explosives during blasting continues to be developed and improved. The use of ammonium nitrate and fuel oils have proven to be effective blasting materials which are safer to transport and handle in bulk quantities. The use of these products has also set a trend of drilling larger holes that are spaced further apart which has aided in reducing labor and equipment cost.

c. Conclusions and Recommendations:

(1) The introduction and development of the hydraulic drill is appealing in that it increases efficiency and reduces labor and fuel cost; however, it is recommended that hydraulic drills not be considered for introduction into the Army's inventory at this time. Drilling equipment manufacturers agree that when the use of hydraulic drilling equipment is compared with the simplicity of air drilling equipment in rugged remote areas, the air drill would be the best suited equipment for military application. The requirement for strict maintenance of hydraulic equipment might also be considered as undesirable in that a large inventory of spare parts and repair equipment would be required to maintain the drills in remote locations.

(2) Continuing the use of air drilling equipment versus changing to hydraulic equipment would not create the domino effect that would occur in changing maintenance, training, procedural, and operational manuals for hydraulic equipment.

(3) Modify Military Specification MIL-D-21201F so that the extendible boom and new efficient drifters can be utilized or considered when replacing or purchasing new drilling equipment.

9. Quarry materials transportation

a. State of the art:

(1) Numerous large established long-term quarries are utilizing conveyor belts for rock transportation in an effort to reduce costs. However, for those quarries that continue to transport rock by truck, industry is developing and manufacturing larger trucks with the idea of one operator and piece of equipment being able to transport larger quantities of material. Trucks capable of transporting 190 tons in one load are being used. End loaders

having bucket capacities of 13 to 15 cu yd are being manufactured to facilitate the loading of these large trucks.

(2) The never-ending effort to cut costs has developed some new and different state-of-the-art production procedures for quarrying aggregates. The initial, or primary, crushers are being located as close to the shot rock or working face as possible. The crushers are fed or loaded directly by front-end wheel loaders. Crushed rock from the Primary crusher is transported out of the quarry to the secondary crushing and screening plants by conveyor belts. As the working face advances, the crushers are moved to keep them in close proximity to the working area. A section of conveyor belt is added to the system to fill the void created by the crushers' advancement. Many times these moves are performed between shifts or during noon breaks so that production is not interrupted. This concept of production eliminates that need for numerous operators and the cost of maintaining a fleet of off-highway trucks.

b. New equipment and developments: The primary new development in quarry materials transportation is the articulated dump truck. The articulation of the truck provides the capability for a large piece of equipment to have a smaller turning radius, therefore enabling it to operate in confined areas, and it also reduces the number of maneuvers required for positioning during loading and unloading operations. The flexibility of this equipment has proved to be successful for off-highway transportation, and it is being produced in various sizes having two-, four-, and six-wheel drive.

c. Conclusions and recommendations:

(1) All indications are that the articulated dump truck would be ideally suited for military application. Its capability for off-highway maneuverability and its overall lower height clearance than conventional quarry trucks (6 ft versus 12 ft) would be desirable qualities for military usage.

(2) The use of conveyors and the deletion of trucks would limit the Army's flexibility of using the trucks for multiple tasks. Therefore, it is recommended that the Army continue to use trucks for quarrying operations.

10. Crushing equipment

a. State of the art:

(1) The size and capacity of the crushing equipment have continually been enlarged and improved in an effort to produce larger quantities of material at lower production cost. There have been few radical or significant changes in equipment or procedures in the rock crushing industry in the last 20 yr; Army has not purchased a quantity of rock crushing equipment in the interim of time. However, there has been some limited research conducted using high

frequency sound and vibration to fracture stone, but these procedures remain in the research and development stages.

(2) Essentially, crushing equipment manufacturers fabricate a piece of equipment to meet a customer's need. The size and production rates of crushing equipment are determined by the initial size and type of rock to be crushed (i.e., quarried shot rock, natural cobble, or dredged gravel). The jaw crusher remains to be the favored primary, or initial, crusher used to reduce rock size. Cone crushers are generally used for secondary crushing. The size of the desired end product will dictate the type of cone that will be used. If finer materials are desired, a flat head, or gyrasphere, cone crusher will be used. Roll crushers are losing favor as high production equipment due to their inefficiency, the quality of their products, and their relatively high maintenance cost. The advantage of a cone versus a roll-type crusher is that the wedge or conical shape of the cone crusher allows for it to be fed various size particles; whereas, the roll-type crusher is limited to a fixed size of material by the space and setting between the rollers.

b. New equipment and developments:

(1) The introduction of the low resonant screen deck has enabled manufacturers to produce a much more reliable and economical piece of equipment. These multideck screens are divided into two parts, or sections, which are joined by coil springs and stabilizer bars. The entire unit is supported on conventional springs. Two self-synchronizing shaker motors provide the exciting or shaking force. This system eliminates wear of parts, such as belts, pullies, and bearings, that are found on conventional screening equipment. The elimination of the unnecessary parts allows for a much more compact, low profile screening unit to be utilized on crushing and processing equipment. The low profile makes the screening units easier to load by end loaders and eliminates the need to construct high bulkheads, retaining walls, and ramps. The lower profile also aids in maneuverability capabilities.

(2) The majority of rock crushing manufacturers produces a single unit crusher consisting of a primary jaw crusher, a secondary cone or roll-type crusher, and a vibratory screen deck to separate the crusher aggregate into various sizes. These units are attractive in that they are compact, and a single piece of equipment can produce larger volumes of materials than can the current 75 ton/hr equipment now in the Army's inventory. The undesirable feature of this single unit crusher equipment is that it is heavy and, depending on the crusher configurations, is near the maximum highway load limitations for some states.

(3) Many manufacturers are installing hydraulic systems or screw jacks on their crushers so they are self-leveling

and self-supporting, this option significantly eliminating manpower and time requirements for movement and erection.

(4) The newest type of crushing equipment that is continuing to be modified and improved is the vertical shaft impact crusher. The crusher works on the principle of a hammermill having hammers or impellers on the vertical shaft. The hammers are rotated at high speed, and rock particles are fractured when they are struck by hammers; additional breakdown occurs when these particles are thrown and driven against other particles or hardened surfaces of the interior of the crushing chamber. This method of size-reduction is desirable because it produces a cubical particle with numerous angular faces. Although this equipment is being used by the aggregate producing industry to improve the quality of its crushed materials, it is felt that it would not be desirable for military application because the hammers and sideplates wear very rapidly and have to be rebuilt or replaced frequently. The weight and number of replacement parts that would be required to maintain this equipment in satisfactory working condition would create a major logistics problem in remote areas.

(5) A recently introduced option being offered by equipment manufacturers are screens made of polyurethanes. These screens have a much longer wear life than conventional wire screens because they are able to resist the wear and abrasion encountered during the screening and sizing cycle of the crushing process. Initially, it was felt that this type of screen would be desirable for military use because it would perform for longer periods of time and would reduce the quantity of spare parts required to keep a crushing unit operating efficiently. Further investigation revealed that these screens are not as efficient as the conventional wire screens. This is because the surface area between the screen openings of the polyurethane screens is larger than conventional wire screens; therefore, it requires a larger screening area or piece of equipment to process the same quantity of material than can be produced by a smaller wire screen. In addition, problems have been encountered in developing a method of securing the polyurethane screens to a vibratory screen deck. Significant developments in these polyurethane screens will be required before the long wear life advantage can offset their cost and justify the replacement of conventional wire screens.

c. Conclusions and recommendations:

(1) Although there have been few significant changes in the types of equipment used to quarry and process quarried materials in the past 20 yr, there have been continuing modifications and improvements to increase production and efficiency. The basic improved equipment now being manufactured should be incorporated into the Army's inventory.

This incorporation can be accomplished with minimal disruption and would not require additional manpower or specialized technicians or training program for the equipment's operation and maintenance.

(2) The duel-unit crushing configuration now being used by engineer units remains favorable in that it provides the opportunity to be flexible. The separate crushing units can be utilized at different locations to process various types of materials. The duel unit crushing configuration increases the number of loads required for transportation, but the total weight is distributed over several chassis providing the capability of much faster equipment movement.

(3) An example of the increased production that could be obtained--if the Army were to incorporate the crushing industry's mid-size equipment, such as a 20 by 36 primary jaw crusher (20 by 36 being the feed opening size in inches), this would enable quarrying units to reduce 18-in. rock into a 3- to 6-in. product at a rate of approximately 93 to 187 tons/hr (tph). A 36-in. secondary cone crusher can be fed 7-in. rock and, depending on the equipment's adjustments, can produce materials ranging from approximately 36 ton/hr of 3/8-in. to 110 ton/hr of 2-in. material. These estimates are made with the understanding that the quality, hardness, the initial size of the material, and the desired size of the end product all have a bearing on production rates and quantities.

(4) Minor procedural changes and the possible addition of three pieces of equipment--larger bucket loader, crusher feeder, and another flat head cone crusher--would enable an engineer quarrying unit to greatly increase the production quantities of crushed materials. The initial feeding or loading of a crusher by bucket loader has proved to be a much more efficient procedure than dumping material directly into the crusher from a truck. However, the use of feeders to load the primary crusher provides an even, uniform flow of raw material. The feeder not only assures uniform production, it also aids in the prevention of chocking or clogging the primary jaw crusher when a surge of shot rock is dumped into the hopper at one time. The addition of a second cone crushing unit would give the engineer unit the capability and versatility of crushing a larger variety of uniform fine material that is required for base course and quality asphalt pavement construction.

(5) The utilization of new optional equipment and accessories that are available should also be addressed when consideration is given to replacing or upgrading the crushing equipment. The incorporation of self-oiling and lubricating systems would assure adequate maintenance procedures. Self-erecting, self-supporting and self-leveling attachments, usually available as optional equipment, would

eliminate the need for timber cribbing used for equipment foundations and support. These options also would would eliminate the requirement of the use of a crane for equipment erection; in addition, they would reduce by several truckloads the amount of equipment and materials associated with crushing equipment demobilization, transportation, and erection. The implementation of all electric powered equipment would be advantageous in that generators could be located away from the crushers, thereby removing them from an unfavorable dusty environment. The use of all electrical power would be advantageous in that industrial electric motors are proving to perform much better than direct diesel powered equipment in a harsh dusty environment.

11. The equipment listed in the following tabulations were selected from literature and specifications that were submitted by those manufacturers responding to a request for quarry and asphalt equipment information. The listings do not represent all equipment that is being manufactured. Only the equipment that is deemed to have the potential for military application is noted.

## DRILLS

| Manufacture Drills | Model No. | Weight lb | Height min in. | Width in. | Ground Clearance in. | Boom Extension Length in. | Boom Swing deg | Boom Horizontal Lift deg | Maximum Distance Vertical Hole, in. | Maximum Drill Height Horizontal in. | Propel Motors HP per Track | Trimming Speed mph | Maximum Borehole Size* in. | International Parts Service |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ingersall Rand | LM 100 | 4,960 | 47.0 | 69.0 | 8.3 | 0 | 45 | 45 | 74 | 93 | 7.0 | 1.8 | 2.5-4.0 | Yes |
| Ingersall Rand | LM 300 | 8,700 | 44.0 | 84.0 | 8.0 | 0 | 0 | 60 | N/A | 120 | 11.4 | 2.5 | 2.5-4.0 | Yes |
| Ingersall Rand | CM 351 | 10,400 | 58.0 | 87.0 | 10.0 | 0 | 45 | 60 | 141 | 133 | 11.4 | 2.75 | 2.5-4.0 | Yes |
| Ingersall Rand | ECM 390 | 12,900 | 49.5 | 96.0 | 10.5 | 60 | 40 | 45 | 260 | 203 | 11.4 | 2.75 | 2.5-4.0 | Yes |
| Gardner Denver | AT 50 | 5,000 | 35.9 | 85.9 | N/A | 0 | 0 | 71 | N/A | 108 | 2.4 | N/A | 2.5-4.0 | No |
| Gardner Denver | ATD 1600A | 8,350 | 51.0 | 86.0 | 9.5 | 0 | 0 | 45 | 111 | 110 | 7.6 | N/A | 2.5-4.0 | No |
| Gardner Denver | ATD 3100B | 9,047 | 58.0 | 86.0 | 9.5 | 0 | 57 | 45 | 152 | 115 | 7.6 | N/A | 2.5-4.0 | No |
| Gardner Denver | ATD 3200B | 10,406 | 60.0 | 86.0 | 9.5 | 0 | 60 | 45 | 155 | 130 | 12.0 | N/A | 2.5-4.0 | No |
| Gardner Denver | ATD 3800 | 12,500 | 63.0 | 93.0 | 12.0 | Optional | 40 | 50 | N/A | N/A | N/A | 1.4 | 2.5-4.0 | No |
| Sullivan Joy | Maverick | 5,840 | 45.0 | 68.0 | 9.0 | 0 | 30 | 62 | N/A | 103 | 8.0 | 1.7 | 2.5-4.0 | No |
| Sullivan Joy | MS 4 | 9,910 | 54.0 | 95.0 | 11.0 | 0 | 38 | 50 | 144 | 122 | 11.5 | 1.7 | 2.5-4.0 | No |
| Sullivan Joy | MS 4E | 13,401 | 65.0 | 95.0 | 11.0 | 60 | 50 | 50 | 312 | 224 | 11.5 | 1.7 | 2.5-4.0 | No |
| Atlas COPCO | ROC 301 | 7,500 | 72.0 | 87.0 | 14.0 | 0 | 0 | 65 | 0 | N/A | 4.0 | 1.27 | N/A | No |
| Atlas COPCO | ROC 302 | 8,264 | 51.0 | 87.0 | 10.0 | 0 | 25 | N/A | 343 | N/A | 4.0 | 1.2 | N/A | |
| Atlas COPCO | ROC 601 | 9,656 | 69.0 | 87.0 | 10.0 | 0 | 45 | 65 | 119 | 12 | 7.0 | 1.5 | N/A | |
| Atlas COPCO | ROC 701 | 13,800 | 53.1 | 86.6 | 14.5 | 0 | 40 | N/A | 113 | N/A | 10.0 | 3.5 | N/A | |
| Atlas COPCO | ROC 400A | 9,810 | 51.0 | 90.0 | 14.0 | 0 | 38 | 62 | 90 | 125 | 7.0 | 1.5 | N/A | |
| Atlas COPCO | ROC 402A | 9,699 | 51.0 | 90.0 | 14.0 | 0 | 38 | 62 | 90 | 125 | 7.0 | 1.5 | N/A | |
| Atlas COPCO | ROC 202A01 | 9,237 | 51.0 | 90.0 | 14.0 | 0 | 38 | 62 | 197 | N/A | 7.0 | 1.5 | N/A | |

* Borehole size is determined by drifter motor selected.

## TRANSPORTATION

| Manufacture | Model | Empty Capacity tons | Weight lb | Height ft | Length ft | Width ft | Cubic Yards Struck | Cubic Yards Heaped | Dump Angle deg | Turning Circle ft | International Parts Service |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Quarry Trucks Dump | | | | | | |
| DRESSLER | 350 | 35.0 | 61,140 | 13.92 | 26.08 | 12.41 | 22.0 | 29.0 | 55 | 49.00 | |
| EUCLID | R 25 | 25.0 | 38,800 | 12.17 | 25.58 | 10.00 | 14.7 | 19.5 | 66 | 53.70 | |
| EUCLID | R 35 | 35.0 | 66,750 | 13.42 | 26.92 | 12.08 | 22.2 | 30.5 | 60 | 53.50 | |
| TEREX | 3305B | 33.0 | 66,000 | 10.08 | 26.00 | 11.41 | 20-0 | 29-0 | 59 | 48.08 | |
| TEREX | 3307 | 40.0 | 80,000 | 14.25 | 27.58 | 13.33 | 25-3 | 29-6 | 58 | 57.00 | |
| TEREX | 3309 | 50.0 | 96,580 | 14.83 | 32.33 | 14.00 | 36-7 | 43-9 | 58 | 61.41 | |
| | | | | | Articulated Dump | | | | | | |
| CATERPILLAR | D 250B | 25.0 | 39,600 | 10.42 | 31.66 | 8.16 | 15.0 | 19.0 | 70 | 48.16 | Yes |
| CATERPILLAR | D 25C | 25.0 | 42,400 | 10.67 | 29.66 | 9.83 | 13.0 | 18.0 | 70 | 49.50 | Yes |
| CATERPILLAR | D 300B | 30.0 | 43,520 | 10.50 | 31.66 | 9.00 | 17.0 | 22.0 | 70 | 48.66 | Yes |
| CATERPILLAR | D 30C | 30.0 | 47,000 | 10.92 | 29.08 | 10.83 | 17.0 | 22.0 | 70 | 50.60 | |
| EUCLID-VOLVO | 5350B | 24.8 | 33,730 | 10.60 | 29.41 | 10.41 | 13.2 | 17.0 | 65 | 49.3 | 4 wheel drive |
| EUCLID-VOLVO | 5350B | 24.8 | 37,919 | 10.80 | 32.25 | 9.16 | 13.6 | 17.0 | 63 | 51.6 | 6 wheel drive |

## CRUSHERS

| Manufacturer | Model | Type | Rated Capacity ton/hr | Weight* | Travel length ft-in. | Travel height ft-in. | Max Feed Size in. | Primary Crusher in. | Secondary Crusher in. | Self Support | Power | No.-Size Screen ft | International Parts Service |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CEDARAPIDS | 322 | Jaw-roll | 10-95 | 50,000 | 34.92 | 14.08 | 9-10 | 10 × 24 | 24 × 16 | Optional | Optional | 3-3.6-10 | No |
| CEDARAPIDS | 575 | Jaw-roll | 40-209 | 93,600 | 45.75 | 15.83 | 11-12 | 12 × 36 | 41 × 30 | Optional | Optional | 3-48 × 14 | No |
| CEDARAPIDS | 766 | Jaw-roll | 40-209 | 102,200 | 66.50 | 12.67 | 15-16 | 16 × 36 | 40 × 26 | Optional | Optional | 3-60 × 14 | No |
| CEDARAPIDS | 3A-VGF | Jaw | 60-265 | 30,822 | 38.50 | 12.58 | 20-22 | 22 × 36 | N/A | Optional | Optional | N/A | No |
| CEDARAPIDS | 7AC-VGF | Jaw | 180-1,000 | 129,700 | 41.75 | 17.00 | 34-36 | 36 × 48 | N/A | Optional | Optional | N/A | No |
| CEDARAPIDS | 1104 | Cone | 36-110 | 54,000 | 52.33 | 14.00 | 7 8 | N/A | 36 | Yes | Electric | 3-41 × 34 | No |
| CEDARAPIDS | 1213 | Cone | 70-188 | 78,000 | 62.92 | 13.67 | 9-10 | N/A | 45 | Yes | Electric | 3-5 × 14 | No |
| PORTEC-PIONEER | 1024 | Jaw | 10-44 | -- | -- | -- | 9-10 | | N/A | Optional | Optional | | No |
| PORTEC-PIONEER | 2036 | Jaw | 93-187 | -- | -- | -- | 19-20 | | N/A | Optional | Optional | | No |
| PORTEC-PIONEER | HMC 1210 | Cone | 62-90 | -- | -- | -- | 4 | | N/A | Optional | Optional | | No |
| PORTEC-PIONEER | HMC 1512 | Cone | 109-145 | -- | -- | -- | 5 | | N/A | Optional | Optional | | No |
| PORTEC-PIONEER | 2416 | Roll | 16-94 | -- | -- | -- | 2 | 24 × 16 | N/A | Optional | Optional | | No |
| PORTEC-PIONEER | 4030 | Roll | 53-640 | -- | -- | -- | 2 | 40 × 30 | N/A | Optional | Optional | | No |
| LIPPMANN | T 1236 | Jaw-roll | | 113,550 | 68.75 | 13.50 | 11-12 | 12 × 36 | 42 × 30 | No | Diesel | 5-52 × 12 | No |
| LIPPMANN | T 1536 | Jaw | | | | 11.00 | 14-15 | 15 × 36 | N/A | | Diesel | | |
| LIPPMANN | L 1800 | Cone | 55-125 | | | | | | | | Electric | | |
| EAGLE | 700 | Impact | | | 56.50 | 13.42 | | | N/A | Yes | Diesel | 2-4 × 12 | No |
| EAGLE | 1000 | Impact | 200-250 | | 61.92 | 13.50 | 24 | 42 × 31 | N/A | Yes | Diesel | 3-5 × 16 | No |
| EAGLE | 3640 | Jaw | 250-600 | | | 11.25 | 12 | | N/A | Yes | Electric | | No |
| TELSMITH | 24-JG-CC | Jaw-Cone | 125-130 | 64,900 | 33.00 | 13.42 | 14-15 | 15 × 24 | 24 | Yes | Electric | 3-3 × 10 | Yes |
| TELSMITH | 36-JG-CC | Jaw-Cone | 130-170 | 127,000 | 57.33 | 9.67 | 19-20 | 20 × 36 | 36 | Yes | Electric | 3-4 × 14 | Yes |
| TELSMITH | 2036 | Jaw | 45-280 | 72,900 | 37.33 | 14.92 | 19-20 | 20 × 36 | N/A | Yes | Electric | N/A | Yes |
| TELSMITH | 1110 | Cone | 90-330 | 85,300 | 44.75 | 12.67 | 5-6 | N/A | 36 | Yes | Electric | 3-5 × 16 | Yes |
| ALLIS CHALMERS | 36 | Cone | 200-300 | 75,000 | 41 | 13.50 | 12 | N/A | 36 | No | Optional | 3-6 × 16 | Yes |
| ALLIS CHALMERS | 45 | Cone | 110-290 | 92,000 | 42.33 | 13.50 | 7 | N/A | 45 | No | Optional | 3-6 × 16 | |
| ALLIS CHALMERS | 13-3 | Cone | 160-300 | 57,000 | 40.42 | 13.50 | 12 | N/A | 36 | No | Optional | 36 | Yes |

* Excluding power source and front travel dolly.

## PART III: ASPHALT EQUIPMENT

12. Part III of this report focuses on the primary pieces of equipment that are used for asphalt concrete production and construction. Auxiliary components and support equipment such as conveyors, loaders and generators are not discussed.

13. Pertinent equipment listed in a standard Table of Organization and Equipment is as follows:

a. Line item No. M57048 MIXING PLANT ASPHALT: Diesel Engine 100 to 150 ton.

b. Line item No. K25215 HEATER HOT OIL TRAILER MOUNTED: Electrical Powered 2100000 Btu output.

c. Line item No. M32780 MELTER ASPHALT: Skid Mounted 750 gal/hr.

d. Line item No. V12312 TANK ASPHALT STORAGE: With Heat Coils 5,000 gal.

e. Line item No. G27844 DISTRIB BITUMIN MATERIAL TANK: Truck Mounted 1,500 gal.

f. Line item No. G27938 DISTRIB LIQUID BITUMIN MATERIAL: Tankless Gas Trailer-Mounted 375 gal/min.

g. Line item No. X44403 TRUCK DUMP: 20-ton Diesel-Driven cu yd Capacity.

h. Line item No. N75124 PAVING MACHINE BITUMINOUS MATERIAL: Gas-Driven Crawler-Mounted 12 ft.

i. Line item No. S11711 ROLLER MOTORIZED STEEL WHEEL: Two-Drum Tandem 10.14 ton.

j. Line item No. S11793 ROLLER PNEUMATIC VARIABLE PRESSURE: Self-propelled.

k. No line item No. ROLLER SINGLE DRUM VIBRATORY: Self-propelled.

14. Asphalt concrete mixing equipment

a. State of the art:

(1) The construction industry is using batch mixing and drum mixing for the production of asphalt concrete. Both procedures are involved and use several individual pieces of equipment during the sequence of production. The continuous-flow type of plant now in the Army's inventory has been discontinued because of its low production rates, difficulty in controlling the materials to produce a consistent mixture, and the numerous pieces of equipment required for production. A comparison of the drum mixer and the equipment now in the Army's inventory is discussed by Tinsman 1982.

(2) The batch plant's sequence of production consists of aggregate being fed into hoppers or cold feeders. The cold feeds discharge the aggregate onto a conveyor belt that elevates and discharges the aggregate into a rotary drying drum. The rotary drum is constructed with one end elevated and has a forced air burner located at the lower end of the drum. The interior of the drum has flights or shelves that pick up the aggregate and let it fall at mid-point of the drum's rotation into the hot-air path that is supplied by the burner. The aggregate is dried as it tumbles and moves down the interior of the drum. A bucket elevator picks up the dried aggregate at the lower end of the dryer drum and feeds it onto a vibratory screen deck located at the top of the plant's tower. The screen deck separates the aggregate into two to four different sizes and discharges it into hot bins located below the screen deck. The desired quantities of aggregate are then discharged into a weight hopper prior to being discharged into the mixing chamber, where a weighed portion of liquid asphalt is added and the mixing of the aggregates and binder is performed by the pugmill. Following mixing, the asphalt is discharged into trucks for delivery to the paver or temporary stored in a silo.

(3) The drum mixer plant's sequence of production consists of aggregate being discharged from a cold feeder. The aggregate is then elevated and deposited into the rotary drum dryer. The drying drum is different from the batch plant because the burner is located on the elevated end of the drum. The aggregate is fed into the drum under the burner. The liquid asphalt is introduced into the drum at the lower end away from the burner. The mixing of the aggregate and the asphalt is performed by the rotation of the drying drum. The mixture is then put into a surge bin to await transportation to the paver.

b. New equipment and developments:

(1) The newest development in asphalt concrete production equipment in recent years is the introduction of the drum mixer. This procedure of mixing asphalt concrete has enabled the asphalt industry to economically increase production to quantities in excess of 600 tons/hr. An appealing aspect of the drum mixer configuration is that the original equipment costs are reduced by the elimination of the screen deck, hot bins, scales, and pugmill components. In addition, the two- or three-story structures required to house the screen deck, lot bins, scales, and pugmill is eliminated. The reduction in the size and number of pieces of equipment has aided in making the new equipment much more transportable, and with some models, a crane is not required for erection of the plants. Several manufacturers produce complete plants that can be transported by six semitrailer loads. This type of equipment has also proved to be successful in the

mixing of virgin material with old crushed pavement for recycling pavements. The Air Force has recently purchased one plant that was designed and constructed to be C-5A transportable.

(2) With the introduction of the drum mixers and the deletion of screens in the mixing equipment, a much greater emphasis has to be placed on the quality and control of the aggregate that is being fed from the cold feeds into the drum. To produce a quality mixture of asphalt concrete, it is mandatory that uniformly consistent materials be used. The cold feed components of the drum mixing plants are designed and constructed to give positive control of the materials that are being fed into the plant. A short conveyor belt, controlled by a variable speed motor, discharges aggregate through an adjustable gate onto a pickup belt that delivers it to the drying drum. The pickup belt is equipped with a metering device that continuously monitors the quantity of aggregate that is being delivered to the mixing drum.

(3) The mixing drums being manufactured at the present time will vary in length and diameter. The variances are basically dependent on the desired production capacity and the material to be dried. The moisture content of the aggregate, altitude above sea level, mixture temperature, and ambient temperature all can have a bearing on the required size of the mixing drum. The length of some drums is being extended in an effort to achieve better heat transfer and mixing during recycling of asphalt concrete mixtures. The interiors of the drums are dissimilar in the respect that different manufacturers are installing various types of baffles or deflectors in an effort to redirect the air, heat, and material flow claiming different and varied benefits resulting from their design. The design, quality, and arrangement of the lifting and mixing flights that are attached to the sides of the drum's interior to aid in mixing and drying are continuing to be improved. Some manufacturers are introducing special mixing chambers and compartments to aid in asphalt concrete mixing and to prevent the emission of hydrocarbons and dust particles into the environment. Many of the drum mixers are constructed with an access opening located near the center of the drum. This opening allows for reclaimed asphalt to be fed into the drum for the recycling of asphalt paving materials.

(4) The fuel consumption efficiency of the blowers and burner assemblies used for heating and drying aggregate materials in the drum mixers has continued to be improved to reduce production costs. Improvements in the burner's capability to flare out and heat larger areas uniformly have been accomplished. A majority of equipment manufacturers are producing burners that can be adjusted to burn a wide variety of fuels ranging from quality fuel oils to low

quality sludges. Newly developed burners fueled with powdered coal are proving to be efficient and economical and are gaining acceptance in many locations of the United States.

(5) The location and procedure for introducing liquid asphalt into the drum mixer differ with the various equipment manufacturer. Generally, the liquid asphalt is metered into the mixer through a constant flow, variable speed pump. The controls are operated in conjunction with the controls of the cold feed pickup belt so that, when there is an increase in the quantity of aggregate being delivered into the drum mixer, the asphalt pump will automatically increase a metered amount of liquid asphalt into the mixture.

(6) The drum mixing procedure for asphalt concrete production is a continuous flow system. A means or procedure of interrupting or stopping the flow of the mixed material for short periods of time is required so that trucks may be switched during the loading sequence of production. The procedure that is successfully and beneficially being used is to store the asphalt concrete mix in a surge bin or storage silo. The surge bin is used to hold small quantities of material for a short period of time; whereas, the silos are intended to hold larger quantities of material for longer periods. Following the mixing of the liquid asphalt and aggregate in the drum mixer, the mixture is elevated by an inclined slat conveyor and deposited into a storage silo. This storage silo is elevated so trucks can drive under for loading. Usually, the silo has a small receiving hopper located under the end of the inclined slat conveyor. The receiving hopper catches the mixed aspnalt concrete and holds it for a short period of time so that a batch or large portion of the mixture will fall into the surge bin at one time. This step aids in preventing segregation of the large and fine particles of aggregate. The construction industry has found the surge bin to be extremely beneficial. Its use provides the capability for advanced preparation and storage of several specified mixtures for various customers. The unit used with smaller portable plants has a capacity of 50 to 60 tons of material. The storage silos used in conjunction with large high production plants will hold and store 200 to 300 tons of mixed materials. These units are insulated and have a heating system to keep the mixed asphalt concrete at a desired temperature until it is loaded into trucks. Many of the surge bins that are manufactured to be used with portable drum mixing plants are self-contained with self-erecting and leveling capabilities. Automatic weighing systems are being built into the surge bins to monitor and record production and delivery. The installation of the weighing

system at the surge bin eliminates the need for a separate truck scales.

(7) With the introduction of the drum mixing process and the procedure of adding the liquid asphalt to the aggregate in the drying chamber, there was anticipation that dust emissions would be eliminated because the dust particles would become coated with asphalt and remain in the asphalt mixture. This has not been the case, and pollution control equipment continues to be required to meet dust particle and hydrocarbon emission limitations. Two methods of emission control (wet and dry) are being offered by the majority of the equipment manufacturers.

(8) The most successful means of dry emission control has been the bag house. Dust and the emissions generated by the dryer that were previously blown into the atmosphere are diverted into a container referred to as a bag house. Circular bag-like fabric filters are suspended inside of vertical tubes. The dust particles are retained by the bag-like filters as the air flows through the tubes. The accumulation of dust is automatically removed from the filtering bags by periodic jets of high pressure air being blown through the inside of the bags. The accumulated dust is then removed from the bag house by an auger to be wasted or partially metered back into the mixer as mineral filler.

(9) Problems of bag-house fires have been encountered with this system because of the lack of adequate maintenance or automatic alarm and cutoff equipment. Hydrocarbons and gases generated from some crude oils have accumulated on the bags and ignited causing damaging fires. The necessity for strict monitoring and maintenance procedures and the cost and difficulty of supplying replacement bags in a remote location might make this type of emission control unattractive for military use.

(10) The alternate procedure for emission control is the wet scrubber. This system picks up the mixing plant's exhaust gases and dust particles and processes them through a high pressure water spray chamber which traps and separates dust particles from the airstream. The undesirable aspect of this procedure of emission control for military application would be its requirement to have an adequate source of water. Settling ponds would be required so that dust sludge could settle out of the water and the water reused. This method also prevents the use of recovered dust as mineral filler in the asphalt mixture.

(11) The equipment and procedures being used for heating and storing liquid asphalt have been modified and greatly improved. Changes have been made to meet the need for economy and efficiency in the industry and for the ease of transportation of portable equipment. The use of high efficiency insulation, improving burner performance, and

the placement of heat exchangers in the hot liquid asphalt to preheat materials have greatly increased the economy and efficiency of heating equipment. Storage tanks are manufactured in different configurations, some having two compartments, so that one segment can store liquid asphalt and the other can store fuel for the burners of the heater and drum mixer. This system is generally used with portable plants to reduce the number of pieces of equipment requiring transportation.

(12) The increased production rates of the drum mixers have required industry to design and produce larger capacity asphalt melters. For remote location construction, asphalt binder is generally transported in 55-gal drums. Mobile units with melting capacities of 1,000 to 2,000 gal/hr and heated storage capacities of 6,500 to 12,500 gal are now available. Skid-mounted 750-gal/hr melters now in the Army's inventory do not have heated storage capacity.

c. Conclusions and recommendations:

(1) The present day state-of-the-art equipment and procedures developed for the production and construction of asphalt concrete are ideally suited for military application. As with the crushing equipment, additional manpower or specialized technicians would not be required for the equipment's operation and maintenance. Sophisticated automatic computer controls are available as an option but are not provided as standard equipment.

(2) The smaller capacity 100- to 400-ton/hr portable drum mixers that are compact and specifically designed for ease of transportation and which are equipped with self-supporting, leveling, and erecting capabilities could easily be incorporated into existing asphalt teams equipment inventory. The incorporation of this equipment should not be disruptive and, depending on the equipment chosen, would increase production capabilities from 100-150 to 100-400 ton/hr with fewer pieces of equipment.

(3) The utilization or addition of recycling equipment and extra liquid asphalt storage capacity would greatly broaden the construction capabilities of an asphalt plant operation team.

(4) The selection of the type of emission control that is best suited to fulfill the military mission requirements is very difficult and should be given careful consideration if specifications for equipment are to be developed. There are logistical considerations to be given in both procedures. An alternative would be to specify emission control equipment that could be used during training exercises but could be bypassed or disconnected in emergency situations.

(5) Consideration might be given to the possibility of obtaining equipment built to a specification allowing for air transportation by C-5A aircraft. In wartime or emergency situations, the option of air transportability could be advantageous.

(6) Special consideration should also be given to placing one of the new types of self-contained pugmill mixing plants that are being manufactured into this unit's equipment inventory. The addition of this one piece of equipment would enable this engineer unit to mix 360 to 650 cu/yd of portland cement concrete that could be utilized as roller compacted concrete pavement. The equipment that is used to place and compact asphalt concrete pavement is also used to place and compact roller compacted concrete. The addition of the one piece of equipment would greatly diversify this unit's capability.

15. Asphalt concrete transportation

a. State of the art. Truck chassis for hauling asphalt concrete change as the truck manufacturing industry changes models. Usually the type of equipment chosen will depend on the type of asphalt paving that is being constructed. Short, bob-tail dump trucks are used for narrow street and driveway-type paving, which requires a lot of maneuvering. Large semitrailer dump trucks are used for highway and airfield paving which requires large volumes of asphalt concrete for continuous paving.

b. New equipment and developments:

(1) The changes that have been made to the asphalt concrete transportation equipment have been mainly to the dump beds. Rounded curved corners have been introduced so that materials will slide out easier and not stick or accumulate in the corners. Insulated and heated truck beds are being used to keep the asphalt concrete mixture hot where haul distances and climatic conditions will have an effect on the temperature of the asphalt.

(2) Large semitrailers capable of hauling in excess of 50 tons are being marketed in some states. These trailers are popular because they are emptied by conveyor instead of lifting. The conveyor system is safer by not elevating heavy loads; it is also convenient where overhead constructions prevent the lifting of dump truck beds.

c. Conclusions and recommendations:

(1) There would be a need for additional hauling equipment if the capacity of the production equipment were upgraded. The proximity of the asphalt mixing plant to the point of asphalt concrete construction would determine the additional number of trucks required for hauling.

(2) Special attention should be given to the type of tailgate that is specified. Instances have occurred when equipment

was purchased and was limited in the work it could perform by the tailgate's inability to open from either the top or bottom; hinging for both openings should be provided.

(3) An increase in the size of hauling equipment would not be advantageous at the present time. The dump truck now in the Army's inventory are sufficient for asphalt concrete transportation.

16. Asphalt concrete construction

a. State of the art. The basic concepts, procedures, and equipment for construction of asphalt concrete have not changed in the last 20 yr. Generally, a specified quantity of liquid asphalt prime coat is applied to a prepared base course material by a truck-mounted asphalt distributor. Following curing of the prime coat, a layer of coarsely graded mixture of asphalt concrete, sometimes referred to as a binder or intermediate course, is applied to the primed base course by an asphalt paving machine. The asphalt concrete is then compacted to a desired density by steel wheeled and rubber tired rollers. An additional light application of liquid asphalt is applied to the compacted asphalt concrete surface to act as a tack coat or bonding agent. The tack coat is followed by an additional lift of finer graded asphalt concrete, referred to as a wearing or surface course. The wearing course is also compacted by rollers to complete the common steps of asphalt concrete pavement construction.

b. New equipment and developments:

(1) The changes and modifications made to the truck bituminous distributors used for spraying liquid asphalt have resulted in greater efficiency and better control of the application of materials. Hydraulic controls for raising and lowering the spray bar are available. Computer and hydraulic control of each individual spray nozzle is also available on request. This optional equipment enables a single operator to regulate the rate and area of application without stopping the distributor to make adjustments.

(2) The asphalt paving machine's basic configuration remains the same, i.e. a tracked or rubber-tired power unit and a spreading screed attached to the power unit by hinged arms. The power unit has a receiving hopper located at its front. Asphalt concrete is deposited into the hopper from the delivery trucks and is then conveyed to the rear of the machine to be spread, leveled, and partially compacted by the screed. Automation of the controls has improved the grade and smoothness of the pavements. The one significant change to the rubber-tired paver is the introduction of four- and six-wheel drive. Previously, a decision had to be made between the speed and mobility of the rubber-tired paver and the power and traction of the tracked paver. With the introduction of four- and six-wheel drive, rubber tired pavers are in competition with

the tracked paver's ability to push loaded trucks on loose material or slippery tack coats.

(3) The screed of the paver has received the greatest attention for improvements and modification. Hydraulic operated screeds are available. These new screeds enable operators to vary the width of the pavement from 10 to 20 ft without stopping or requiring tools and auxiliary screed extensions. Adjustments for slope and crown of the pavement can also be made automatically. Some screeds are being increased in length to offset the tendency of the screed to rise and have a skiing effect when the machine starts. The reintroduction of the tamping bar is being considered by some US manufacturers to meet foreign competition. The tamping bar screed lost favor as a means of initial compaction to the vibratory screen because slower movement was required for the mechanical action of the tamping bar to be effective. Interest in the tamping bar has been regenerated because of its success in placing roller-compacted concrete and thick lifts of aggregate base course materials.

(4) Automatic controls for grade and pavement thickness continue to be improved. There has been some work accomplished using lasers for grade control. These devices are still being improved and developed. Sensors to control the quantity of material distributed by the augers in front of the screed are available as optional equipment.

(5) The rollers that are used to compact asphalt concrete have had few changes. The self-propelled vibratory roller is the newest introduction to compaction equipment. The articulated vibratory and pneumatic rollers are also recent introductions. An articulated roller that has a vibratory steel drum in front and four pneumatic-tired wheels in back is being used in Europe and has recently been introduced in the United States. Metal drums having a covering of hard rubber have been demonstrated; the coating of rubber decreases the noise generated by the vibrations of the drum and is also promoted as decreasing aggregate break-down during seal coat construction.

c. Conclusions and recommendations:

(1) The asphalt concrete construction equipment being used by the construction industry could easily be incorporated into the Army's inventory. A requirement for sophisticated controls for bituminous distributors cannot be justified at the present time. Standard distributor equipment can fulfill the mission.

(2) The four-wheel drive paving machine would be desirable because of its increased power and ability to travel at higher speed and its maneuverability. The hydraulic extendable screed may be attractive, but there could be problems with then in remote locations. A standard

extendable screed with crown adjustment capabilities would be desirable for military usage. The requirement for a tamping bar would provide for the paver to be used for multiple tasks. Standard state-of-the-art grade control accessories should also be used.

(3) The articulated vibratory rollers would be advantageous in that they would provide greater compaction capacities than a static roller and have better maneuverability. The articulated vibratory steel-drum pneumatic-tired roller that has recently been introduced is ideal for military application. A single piece of equipment can be utilized for multiple tasks. Additional heavy rolling equipment would be required if a team's mission were to construct asphalt concrete airfields or storage areas that require high density compaction. It is doubtful that the rollers now in the Army's inventory would be able to achieve the designed density for airfields or storage areas. Experience has proved that rollers with a minimum of 20-25 ton capacity are required to achieve these requirements.

## PART IV: SUMMARY

17. Numerous models of quarrying and asphalt equipment that are now being produced by equipment manufacturers for the private industry are ideally suited for military application. To remain competitive in the industry it has become necessary for manufacturers to design and produce equipment that have high production capabilities but remain compact and are easily transportable. These characteristics are desirable for military application. Additional favorable factors are that by not having radical changes in design or operational procedure the equipment can be incorporated into a unit's equipment inventory with minimal requirements for changing training and operational manuals and procedures.

18. The equipment listed in the following tabulations were selected from literature and specifications that were submitted by those manufacturers responding to request for quarry and asphalt equipment information. The listings do not represent all equipment that is being manufactured. In addition, only the equipment that is deemed to have the potential for military application is noted.

ASPHALT/DRUM MIXING EQUIPMENT

| Manufactures Mixers | Model | Capacity ton/hr | Weight | Travel Height ft | Travel Length ft | Type Emission Control | Self Erect | Self Support | Recycle Capable | Eng. for Air Transport | International Parts Service | Power |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CEDARAPIDS | 4820 | 40-89 | 31,500 | 21.50 | 41.42 | Wet | Yes | Yes | No | No | No | Electric |
| CEDARAPIDS | 6422 | 82-177 | 44,240 | 13.00 | 48.42 | Wet | Yes | Yes | No | No | No | Electric |
| CEDARAPIDS | 7224 | 107-237 | 49,000 | 13.50 | 50.00 | Wet | Yes | Yes | No | No | No | Electric |
| CEDARAPIDS | 8828 | 162-356 | 75,400 | 13.67 | 57.83 | Optional | No | Yes | Yes | No | No | Electric |
| PORTEC-PIONEER | 60-20E | 37-85 | 30,000 | 14.00 | 70.00 | Wet | Yes | Yes | No | No | No | Electric |
| PORTEC-PIONEER | 60-200M | 62-142 | 30,000 | 13.50 | 64.00 | Wet | Yes | No | Yes | No | No | Electric |
| PORTEC-PIONEER | 72-26B | 120-204 | 31,000 | 14.00 | 55.50 | Wet | No | No | Optional | No | No | Electric |
| PORTEC-PIONEER | 72-26E | 120-204 | 31,000 | 14.00 | 55.50 | Wet | No | No | Optional | No | No | Electric |
| STANDARD HAVENS | | | | | | | Yes | Yes | | | | |
| BMG CORPORATION | 30 R 20 | 100-350 | 70,000 | 13.50 | 85 | Optional | Yes | Yes | Yes | No | No | Electric |
| BMG CORPORATION | 40 R 30 | 100-450 | 84,600 | 13.50 | 89 | Optional | Yes | Yes | Yes | No | No | Electric |
| CMI | UVM 1000 | 230 | 70,000 | 13.83 | 60.92 | Wet | Yes | Yes | Yes | No | Yes | Electric |
| CMI | PVM 1100 | 245 | 55,000 | 13.75 | 61.42 | Optional | Yes | Yes | Yes | No | Yes | Electric |
| CMI | UVM 1400 | 270 | 76,000 | 13.92 | 64.92 | WET | Yes | yes | Yes | No | Yes | Electric |
| CMI | PVM 1500 | 285 | 69,440 | 13.92 | 63.75 | Optional | Yes | Yes | Yes | No | Yes | Electric |
| CMI | PVM 2000 | 365 | 80,390 | 13.92 | 68.33 | Optional | Yes | Yes | Yes | No | Yes | Electric |
| H&B/WHITE | | | | | | | | | | | | |
| AEDCO/MIDLAND | 54265 | 30-600 | 31,000 | 12.0 | 50 | Wet | Yes | Yes | Optional | No | No | Electric |
| BITUMA/GENCOR | | | | | | | | | | | | |
| ASTEC/BARBER GREEN | 85-151 | 125 | | 11.50 | 51.42 | Dry | Yes | Yes | Yes | Yes | Yes | Electric |

SURGE BIN

| Manufacturer | Model | Capacity ton | Travel Length ft | Travel Height ft | Weight lb | Self Erect | Reject Bypass | Built in Scales | Truck Drive Through ft |
|---|---|---|---|---|---|---|---|---|---|
| CMI | SE 652 | 65 | 50.00 | 14.01 | | Yes | Yes | Yes | 12.25 |
| BITUMA | 170 | 170 | -- | -- | -- | Yes | Yes | No | -- |
| CEDARAPIDS | 300 | 65 | 41.08 | 14.00 | | Yes | Yes | Yes | 12.75 |
| ASTEC/BARBER GREEN | P-6 | 100 | | | | Yes | Yes | Yes | |
| AEDCO | | 80 | | | | Yes | | Yes | |

## PAVERS

| Manufacturer | Model | Length ft | Height ft | Width ft | Weight lb | Drive | Speed Paving FPM | Speed Travel MPH | Turn Radius ft | Screed Width ft-in. | Screed Extension |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CEDARAPIDS | BSF 420 | 16.42 | 8.00 | 10.50 | 24,300 | Track | 0-106 | 0-4 | | 10 | 20 |
| CEDARAPIDS | BSF 330 | 16.42 | 8.42 | 8.00 | 19,500 | Tire | 0-150 | 0-4.5 | 12-0 | 10 | 15 |
| CEDARAPIDS | CR 431 | 18.50 | 8.25 | 10.00 | 27,000 | Tire | 0-150 | 0-5 | | 10 | 24 |
| CEDARAPIDS | CR 531 | 20.42 | 8.25 | 10.50 | 31,000 | Tire | 0-166 | 0-4 | | 10 | 30 |
| CATERPILLAR | AP 200 | 8.00 | 6.67 | 8.00 | 9,000 | Track | | | | 9 | 12 |
| CATERPILLAR | AP 800 | 20.42 | 9.67 | 10.75 | 29,150 | Tire | 0-312 | 0-13 | | 8 | 20 |
| CATERPILLAR | AP 1200 | 20.50 | 8.75 | 10.00 | 36,500 | Tire | 0-254 | 0-13 | | 10 | 19-6 |
| BLAW KNOX | PF 150 | 14.58 | | 10.42 | 15,300 | Tire | | | | 6 | 12-6 |
| BLAW KNOX | PF 22 | 11.83 | | 10.00 | 9,500 | Tire | 0-60 | 0-4 | | 5 | 12 |
| BLAW KNOX | PF 35 | 12.92 | | 10.08 | 10,340 | Tire | 0-130 | 0-18 | | 6 | 12 |
| BLAW KNOX | PF 115 | 16.58 | | 9.25 | 19,700 | Tire | 0-133 | 0-12 | | 8 | 15 |
| BLAW KNOX | PF 120 | 18.75 | | 10.00 | 21,920 | Tire | 0-296 | 0-13 | | 10 | 21 |
| BLAW KNOX | PF 400A | 17.58 | | 9.92 | 25,940 | Track | 0-150 | 0-6 | | 16 | 25 |
| *ROADTEC/BARBER GREEN | 445 | 19.25 | 8.83 | 10.17 | 26,000 | Tire | 0-170 | 0-11 | 10-6 | 8 | 22 |
| TITAN ABG | 420 | 18.17 | 10.00 | 9.67 | 38,000 | Track | 0-300 | 0-15 | N/A | 10 | 40 |
| VOGELE | N/A | N/A | | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| PAVE SAVER | N/A | N/A | | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

* ROADTEC/BARBER GREEN has been licensed by Titan ABG to manufacture their heavy duty tamping bar screed.

Articulated Double Drum Vibratory Rollers

| Manufacturer | Model | Length ft | Width ft | Height ft | Weight Without Ballast Weight | Maximum Operating Weight lb | Turning Radius I - inside O - outside | Drum Width in. | Drum Diameter in. | Vibration/ min |
|---|---|---|---|---|---|---|---|---|---|---|
| CATERPILLAR | CB 224 | 7.83 | 4.25 | 6.75 | 5,072 | 5,400 | I-7-11 | 47.2 | 27.5 | 3,000 |
| CATERPILLAR | CB 314 | 10.67 | 4.00 | 6.50 | 6,500 | 7,400 | I-5-8 | 44-0 | 30-0 | 3,000 |
| CATERPILLAR | CB 414 | 14.50 | 5.33 | 6.83 | 12,100 | 12,750 | I-14-1 | 55.0 | 42.0 | 3,000 |
| CATERPILLAR | CB 514 | 16.67 | 6.50 | 7.33 | 20,000 | 21,450 | I-16-4 | 68.0 | 48.0 | 2,550 |
| CATERPILLAR | CB 614 | 18.33 | 7.92 | 8.33 | 22,600 | 25,000 | I-17-6 | 78.0 | 54.0 | 2,300 |
| INGERSOIL RAND | DA 28 | 8.17 | 3.58 | 5.58 | 4,700 | 5,060 | 0-12-0 | 39.0 | 28.0 | 3,300 |
| INGERSOIL RAND | DD 35 | 10.33 | 3.58 | 5.67 | 6,300 | 7,050 | 0-11-2 | 40.0 | 30.0 | 4,000 |
| INGERSOIL RAND | DD 65 | 13.67 | 5.00 | 7.50 | 13,450 | 14,500 | 0-14-5 | 55.0 | 41.0 | 3,000 |
| INGERSOIL RAND | DD 90 | 17.50 | 5.83 | 7.25 | 18,790 | 20,060 | 0-17-0 | 66.0 | 48.0 | 2,500 |
| DYNAPAC | CC 10 | 7.75 | 3.67 | 5.50 | 5,027 | 5,358 | 0-10-5 | 42.0 | 26.0 | 3,000 |
| DYNAPAC | CC 12 | 7.75 | 4.50 | 5.50 | 5,220 | 5,550 | 0-11-5 | 47.0 | 26.0 | 3,000 |
| DYNAPAC | CC 14 | 11.50 | 4.75 | 6.67 | 8,820 | 9,590 | 0-14-7 | 51.0 | 35.0 | 2,500 |
| DYNAPAC | CC 21 | 14.75 | 4.58 | 7.08 | 14,110 | 15,100 | 0-15-7 | 57.0 | 41.0 | 2,900 |
| DYNAPAC | CC 42 | 18.67 | 5.75 | 7.50 | 20,700 | 22,250 | 0-20-6 | 66.0 | 48.0 | 2,500 |
| BOMAG | BW 100 | 7.75 | 3.42 | 5.17 | 4,123 | 4,505 | I-9-0 | 39.0 | 25.0 | 3,300 |
| BOMAG | BW 120 | 7.33 | 4.75 | 5.42 | 5,038 | 5,457 | I-8-9 | 47.0 | 26.0 | 3,300 |
| BOMAG | BW 141 | 12.00 | 5.17 | 7.17 | 13,561 | 14,619 | I-12-7 | 55.0 | 30.0 | 3,300 |
| BOMAG | BW 201 | 14.50 | 7.50 | 7.50 | 20,992 | 22,248 | I-14-3 | 84.0 | 48.0 | 2,700 |

Combination Vibrating Steel-Drum Pneumatic-Tired Rollers

| Manufacturer | Model | Length ft | Width ft | Height ft | Weight Without Ballast Weight | Maximum Operating Weight lb | Turning Radius I - inside O - outside | Drum Width in. | Drum Diameter in. | Vibration/ min |
|---|---|---|---|---|---|---|---|---|---|---|
| BOMAG | BW 141 AC | 12.00 | 4.58 | 7.00 | 13,064 | 14,112 | I-12-7 | 55.0 | 41.0 | 3,300 |
| BOMAG | BW 151 AC | 12.00 | 5.42 | 7.00 | 13,627 | 14,663 | I-12-3 | 66.0 | 41.0 | 3,300 |
| BOMAG | BW 160 AC | 13.75 | 5.42 | 7.83 | 15,347 | 16,583 | I-18-7 | 66.0 | 47.0 | 2,900 |

# REFERENCE


Tinsman, Andrew, C. 1982. "Bituminous Equipment Systems", Report No. 2351, US Army Mobility Equipment Research and Development Command, Fort Belvoir, VA.